AWS D1.1/D1.1M:2002
An American National Standard

Structural Welding Code—Steel

American Welding Society

Approved American National Standard
ANSI

4. Qualification

4.0 Scope

The requirements for qualification testing of welding procedure specifications (WPSs) and welding personnel are described as follows:

Part A—General Requirements. This part covers general requirements of both WPS and welding personnel performance requirements.

Part B—Welding Procedure Specification (WPS). This part covers the qualification of a WPS that is not classified as prequalified in conformance with Section 3.

Part C—Performance Qualification. This part covers the performance qualification tests required by the code to determine a welder's, welding operator's, or tack welder's ability to produce sound welds.

Part A
General Requirements

4.1 General

The requirements for qualification testing of WPSs and welding personnel (defined as welders, welding operators, and tack welders) are described in this section.

4.1.1 Welding Procedure Specification (WPS). Except for prequalified WPSs in conformance with Section 3, a WPS for use in production welding shall be qualified in conformance with Section 4, Part B, and shall be approved by the Engineer. Properly documented evidence of previous WPS qualification may be accepted with the Engineer's approval. The requirements listed in Annex IV, Table IV-1, Code Requirements That May be Changed by WPS Qualification Tests, may be varied when the WPS is qualified by tests.

4.1.1.1 Qualification Responsibility. Each manufacturer or Contractor shall conduct the tests required by this code to qualify the WPS. Properly documented WPSs qualified under the provisions of this code by a company that later has a name change due to voluntary action or consolidation with a parent company may utilize the new name on its WPS documents.

4.1.1.2 Previous WPS Qualification. The Engineer may accept properly documented evidence of previous qualification of the WPSs that are to be employed. The acceptability of qualification to other standards is the Engineer's responsibility, to be exercised based upon the specific structure, or service conditions, or both. AWS B2.1.XXX-XX Series on Standard Welding Procedure Specifications may, in this manner, be accepted for use in this code.

4.1.1.3 CVN Test Requirements. When required by contract drawings or specifications, CVN tests shall be included in the WPS qualification. The CVN tests, requirements, and procedure shall be in conformance with the provisions of Annex III, or as specified in the contract documents.

4.1.2 Performance Qualification of Welding Personnel. Welders, welding operators and tack welders to be employed under this code, and using the shielded arc welding SMAW, SAW, GMAW, GTAW, FCAW, ESW, or EGW processes, shall have been qualified by the applicable tests as described in Part C of this section (see Commentary).

4.1.2.1 Previous Performance Qualification. Properly documented evidence of previous performance qualification of welders, welding operators and tack welders may be accepted with the Engineer's approval. The acceptability of performance qualification to other standards is the Engineer's responsibility, to be exercised based upon the specific structure, or service conditions, or both. Welders and welding operators qualified by standard test to AWS B2.1, *Standard for Welding Procedure and Performance Qualification*, may, in this manner, be accepted for use in this code.

4.1.2.2 Qualification Responsibility. Each manufacturer or Contractor shall be responsible for the qualification of welders, welding operators and tack welders, whether the qualification is conducted by the manufacturer, Contractor, or an independent testing agency.

4.1.3 Period of Effectiveness

4.1.3.1 Welders and Welding Operators. The welder's or welding operator's qualification as specified in this code shall be considered as remaining in effect indefinitely unless (1) the welder is not engaged in a given process of welding for which the welder or welding operator is qualified for a period exceeding six months or unless (2) there is some specific reason to question a welder's or welding operator's ability (see 4.32.1).

4.1.3.2 Tack Welders. A tack welder who passes the test described in Part C or those tests required for welder qualification shall be considered eligible to perform tack welding indefinitely in the positions and with the process for which the tack welder is qualified unless there is some specific reason to question the tack welder's ability (see 4.32.2).

4.2 Common Requirements for WPS and Welding Personnel Performance Qualification

4.2.1 Qualification to Earlier Editions. Qualifications which were performed to and met the requirements of earlier editions of AWS D1.1 or AWS D1.0 or AWS D2.0 while those editions were in effect are valid and may be used. The use of earlier editions shall be prohibited for new qualifications in lieu of the current editions, unless the specific early edition is specified in the contract documents.

4.2.2 Aging. When allowed by the filler metal specification applicable to weld metal being tested, fully welded qualification test specimens may be aged at 200°F to 220°F [95°C to 105°C] for 48 ± 2 hours.

4.2.3 Records. Records of the test results shall be kept by the manufacturer or Contractor and shall be made available to those authorized to examine them.

4.2.4 Positions of Welds. All welds shall be classified as flat (F), horizontal (H), vertical (V), and overhead (OH), in conformance with the definitions shown in Figures 4.1 and 4.2.

Test assembly positions are shown in:

(1) Figure 4.3 (groove welds in plate)

(2) Figure 4.4 (groove welds in pipe or tubing)

(3) Figure 4.5 (fillet welds in plate)

(4) Figure 4.6 (fillet welds in pipe or tubing)

Part B
Welding Procedure Specification (WPS)

4.3 Production Welding Positions Qualified

The production welding positions qualified by a WPS shall conform to the requirements of Table 4.1.

4.4 Type of Qualification Tests

The type and number of qualification tests required to qualify a WPS for a given thickness, diameter, or both, shall conform to Table 4.2 (CJP), Table 4.3 (PJP) or Table 4.4 (fillet). Details on the individual NDT and mechanical test requirements are found in the following subsections:

(1) Visual Inspection (see 4.8.1)

(2) NDT (see 4.8.2)

(3) Face, root and side bend (see 4.8.3.1)

(4) Reduced Section (see 4.8.3.4)

(5) All-Weld-Metal Tension (see 4.8.3.6)

(6) Macroetch (see 4.8.4)

4.5 Weld Types for WPS Qualification

For the purpose of WPS qualification, weld types shall be classified as follows:

(1) CJP groove welds for Nontubular Connections (see 4.9)

(2) PJP groove welds for Nontubular Connections (see 4.10)

(3) Fillet Welds for Tubular and Nontubular Connections (see 4.11)

(4) CJP groove welds for Tubular Connections (see 4.12)

(5) PJP groove welds for Tubular T-, Y-, and K-connections and Butt Joints (see 4.13)

(6) Plug and Slot welds for Tubular and Nontubular Connections (see 4.14)

Inspector. Assistant Inspectors shall be qualified by training and experience to perform the specific functions to which they are assigned. The work of Assistant Inspectors shall be regularly monitored by the Inspector, generally on a daily basis.

6.1.4.4 Eye Examination. Inspectors and Assistant Inspectors shall have passed an eye examination with or without corrective lenses to prove: (1) near vision acuity of Snellen English, or equivalent, at no less than 12 in. [300 mm]; and (2) far vision acuity of 20/40, or better. Eye examination of all inspection personnel shall be required every three years or less if necessary to demonstrate adequacy.

6.1.4.5 Verification Authority. The Engineer shall have authority to verify the qualification of Inspectors.

6.1.5 Inspector Responsibility. The Inspector shall ascertain that all fabrication and erection by welding is performed in conformance with the requirements of the contract documents.

6.1.6 Items to be Furnished to the Inspector. The Inspector shall be furnished complete detailed drawings showing the size, length, type, and location of all welds to be made. The Inspector shall also be furnished the portion of the contract documents that describes material and quality requirements for the products to be fabricated or erected, or both.

6.1.7 Inspector Notification. The Inspector shall be notified in advance of the start of operations subject to inspection and verification.

6.2 Inspection of Materials

The Contractor's Inspector shall make certain that only materials conforming to the requirements of this code shall be used.

6.3 Inspection of WPSs and Equipment

6.3.1 WPS. The Inspectors shall review all WPSs to be used for the work and shall make certain that the procedures conform to the requirements of this code.

6.3.2 Welding Equipment. The Inspector shall inspect the welding equipment to be used for the work to make certain that it conforms to the requirements of 5.11.

6.4 Inspection of Welder, Welding Operator, and Tack Welder Qualifications

6.4.1 Determination of Qualification. The Inspector shall allow welding to be performed only by welders, welding operators, and tack welders who are qualified in conformance with the requirements of Section 4, or shall make certain that each welder, welding operator, or tack welder has previously demonstrated such qualification under other acceptable supervision and approved by the Engineer in conformance with 4.1.2.1.

6.4.2 Retesting Based on Quality of Work. When the quality of a qualified welder's, welding operator's, or tack welder's work appears to be below the requirements of this code, the Inspector may require that the welder, welding operator, or tack welder demonstrate an ability to produce sound welds by means of a simple test, such as the fillet weld break test, or by requiring complete requalification in conformance with Section 4.

6.4.3 Retesting Based on Qualification Expiration. The Inspector shall require requalification of any qualified welder or welding operator who has not used the process (for which they are qualified) for a period exceeding six months (see 4.1.3.1).

6.5 Inspection of Work and Records

6.5.1 Size, Length, and Location of Welds. The Inspector shall make certain that the size, length, and location of all welds conform to the requirements of this code and to the detail drawings and that no unspecified welds have been added without approval.

6.5.2 WPS. The Inspector shall make certain that only WPSs are employed which meet the provisions of Section 3 or Section 4.

6.5.3 Electrode Classification and Usage. The Inspector shall make certain that electrodes are used only in the positions and with the type of welding current and polarity for which they are classified.

6.5.4 Scope of Examinations. The Inspector shall, at suitable intervals, observe joint preparation, assembly practice, the welding techniques, and performance of each welder, welding operator, and tack welder to make certain that the applicable requirements of this code are met.

6.5.5 Extent of Examination. The Inspector shall examine the work to make certain that it meets the requirements of this code. Other acceptance criteria, different from those described in the code, may be used when approved by the Engineer. Size and contour of welds shall

C4. Qualification

Part A
General Requirements

C4.1.1.1 Qualification Responsibility. All Contractors shall be responsible for their final product. Therefore, it is their responsibility to comply with the qualification requirements of the code relative to WPSs. Properly documented WPSs and personnel qualification tests conducted by the Contractor in conformance with this code are generally acceptable to the Engineer for the contract.

C4.1.2 Performance Qualification of Welding Personnel. The qualification tests are especially designed to determine the ability of the welders, welding operators, and tack welders to produce sound welds by following a WPS. The code does not imply that anyone who satisfactorily completes qualification tests can do the welding for which they are qualified for all conditions that might be encountered during production welding. It is essential that welders, welding operators, and tack welders have some degree of training for these differences.

Ideally, welders, welding operators and tack welders welding quenched and tempered high-strength steels should have experience welding such base metals. In lieu of such experience, the Contractor should ensure that the Contractor's personnel receive instruction and training in the welding of such steels. It is further recommended that other personnel, such as fitters and thermal cutters (burners) involved in fabrication utilizing quenched and tempered high-strength steel be experienced or receive instruction and training prior to the start of thermal cutting operations.

C4.1.3.1 Period of Effectiveness—Welders and Welding Operators. This subsection controls the expiration date of a welder's qualification. The qualification remains in effect (1) for six months beyond the date that the welder last used the welding process, or (2) until there is a specific reason to question the welder's ability. For (1), the requalification test need be made only in 3/8 in. [10 mm] thickness using plate or pipe or both. If the welder fails this test, then requalification shall follow the requirements of Section 4, Part C, Welding Personnel Performance Qualification. For (2), the type of test should be mutually agreed upon between the Contractor and the Engineer and shall be within the requirements of Section 4, Part C, Performance Qualification.

C4.2.4 Positions of Test Welds. This subsection defines welding positions for qualification test welds and production welds. Position is an essential variable for all of the WPSs, except for the EGW and ESW processes which are made in only one position. Each WPS shall be qualified for each position for which it will be used in fabrication. Relationships between the position and configuration of the qualification test weld and the type of weld and positions qualified are shown in Table 4.1. It is essential to perform testing and evaluation of the welds to be encountered in construction prior to their actual use on the job. This will assure that all the necessary positions are tested as part of the qualification process.

Part B
WPS Qualification

C4.4 Type of Qualification Tests

Table 4.2 summarizes the requirements for the number and type of test specimens and the range of thicknesses qualified. A test plate thickness of 1 in. [25 mm] or over qualifies a WPS for unlimited thickness. The 1 in. [25 mm] thickness has been shown to generally reflect the influence of weld metal chemistry, heat input, and preheat temperature on the weld metal and HAZ. The term *direction of rolling* was made optional in the 1988 edition, although the mechanical properties of steel plate may vary significantly with the direction of rolling and may affect the test results. For example, tensile strength

representing the Owner and the Inspector representing the Contractor.

C6.1.5 Inspector Responsibility. This subsection requires that the Inspector verify that all fabrication and erection by welding is performed in conformance with the requirements of the contract documents. This includes not only welding but also materials, assembly, preheating, NDT, and all other requirements of the code and provisions of the contract documents.

C6.1.6 Items to be Furnished to the Inspector. Inspectors need a complete set of approved drawings to enable them to properly do their work. They need be furnished only the portion of the contract documents describing the requirements of products that they will inspect. Much of the contract documents deal with matters that are not the responsibility of the Inspector; these portions need not be furnished.

C6.1.7 Inspector Notification. If the Inspectors are not notified in advance of the start of operations, they cannot properly perform the functions required of them by the code.

C6.2 Inspection of Materials

This code provision is all-encompassing. It requires inspection of materials and review of materials certification and mill test reports. It is important that this work be done in a timely manner so that unacceptable materials are not incorporated in the work.

C6.3 Inspection of WPS Qualification and Equipment

The requirements of 6.3.1 and 6.3.2, including any qualification testing required by Section 4, should be completed before any welding is begun on any weldments required by the contract documents. Qualification should always be done before work is started, but all qualification does not have to be completed before any work can be started.

C6.4 Inspection of Welder, Welding Operator, and Tack Welder Qualifications

C6.4.1 Determination of Qualification. It is important that the Inspector determine that all welders are qualified before work is begun on the project. If discovered after welding has begun, lack of welder qualification documentation may cause serious delays in the acceptance of weldments.

C6.4.2 Retesting Based on Quality of Work. The inspector shall regularly appraise the quality of welds produced by welders, welding operators, and tack welders. Individuals producing unacceptable welds should be required to produce satisfactory test welds of the type causing difficulties. Complete requalification may not always be necessary. Only qualified welders producing acceptable welds may be employed in the work.

C6.4.3 Retesting Based on Certification Expiration. Welders who cannot provide evidence that they have used, without interruption, the welding process for which they were qualified, for a period exceeding six months, shall be requalified by appropriate tests. Since active welders can maintain their certification as long as they continue to do good work, it is essential that Inspectors regularly evaluate the quality of the welds produced by each welder, welding operator, and tack welder.

C6.5 Inspection of Work and Records

Except for final visual inspection, which is required for every weld, the Inspector shall inspect the work at suitable intervals to make certain that the requirements of the applicable sections of the code are met. Such inspections, on a sampling basis, shall be prior to assembly, during assembly, and during welding. The inspector shall identify final acceptance or rejection of the work either by marking on the work or with other recording methods. The method of identification should not be destructive to the weldment. Die stamping of welds is not recommended since die stamp marks may form sites for crack initiation.

C6.6.1 Contractor Responsibilities. Contractors shall be responsible for the acceptability of their products. They shall conduct inspection to the extent necessary to ensure conformance with the code, except as provided in 6.6.5.

C6.6.2 Inspector Requests. If the Inspector(s) find deficiencies in the materials and workmanship, regardless of whether the Inspector(s) is a representative of the Owner or an employee of the Contractor, the Contractor shall be responsible for all necessary corrections.

C6.6.4 Specified NDT Other than Visual. When NDT is specified in the information furnished to bidders, the Contractor shall take necessary steps to ensure that the NDT acceptance criteria prescribed by the code are met. When NDT other than visual inspection is not specified, the Owner shall be responsible for all associated costs of testing and surface preparation plus the repair of discon-

Annex B

Terms and Definitions

(This Annex is not a part of AWS D1.1/D1.1M:2002, *Structural Welding Code—Steel*, but is included for information purposes only.)

The terms and definitions in this glossary are divided into three categories: (1) general welding terms compiled by the AWS Committee on Definitions and Symbols; (2) terms, defined by the AWS Structural Welding Committee, which apply only to UT, designated by (UT) following the term; and (3) other terms, preceded by asterisks, which are defined as they relate to this code.

A

***alloy flux.** A flux upon which the alloy content of the weld metal is largely dependent.

***all-weld-metal test specimen.** A test specimen with the reduced section composed wholly of weld metal.

***amplitude length rejection level (UT).** The maximum length of discontinuity allowed by various indication ratings associated with weld size, as indicated in Tables 6.2 and 6.3.

***angle of bevel.** See **bevel angle**.

arc gouging. Thermal gouging that uses an arc cutting process variation to form a bevel or groove.

as-welded. The condition of weld metal, welded joints, and weldments after welding, but prior to any subsequent thermal, mechanical, or chemical treatments.

***attenuation (UT).** The loss in acoustic energy which occurs between any two points of travel. This loss may be due to absorption, reflection, etc. (In this code, using the shear wave pulse-echo method of testing, the attenuation factor is 2 dB per inch of sound path distance after the first inch.)

automatic welding. Welding with equipment that requires only occasional or no observation of the welding, and no manual adjustment of the equipment controls. Variations of this term are **automatic brazing, automatic soldering, automatic thermal cutting**, and **automatic thermal spraying**.

***auxiliary attachments.** Members or appurtenances attached to main stress-carrying members by welding. Such members may or may not carry loads.

axis of a weld. See **weld axis**.

B

backgouging. The removal of weld metal and base metal from the weld root side of a welded joint to facilitate complete fusion and CJP upon subsequent welding from that side.

backing. A material or device placed against the back side of the joint, or at both sides of a weld in ESW and EGW, to support and retain molten weld metal. The material may be partially fused or remain unfused during welding and may be either metal or nonmetal.

backing pass. A weld pass made for a backing weld.

backing ring. Backing in the form of a ring, generally used in the welding of pipe.

backing weld. Backing in the form of a weld.

***backup weld (tubular structures).** The initial closing pass in a CJP groove weld, made from one side only, which serves as a backing for subsequent welding, but is not considered as a part of the theoretical weld (Figures 3.8 through 3.10, Details C and D).

back weld. A weld made at the back of a single groove weld.

base metal. The metal or alloy that is welded, brazed, soldered, or cut.

bevel angle. The angle between the bevel of a joint member and a plane perpendicular to the surface of the member.

box tubing. Tubular product of square or rectangular cross section. See **tubular**.

***brace intersection angle, θ (tubular structures).** The acute angle formed between brace centerlines.

***Building Code.** The term *Building Code*, whenever the expression occurs in this code, refers to the building law or specification or other construction regulations in conjunction with which this code is applied. In the absence of any locally applicable building law or specifications or other construction regulations, it is recommended that the construction be required to comply with the *Specification for the Design, Fabrication, and Erection of Structural Steel for Buildings of the American Institute of Steel Construction* (AISC).

butt joint. A joint between two members aligned approximately in the same plane.

butt weld. A nonstandard term for a weld in a butt joint. See **butt joint**.

C

***cap pass.** One or more weld passes that form the weld face (exposed surface of completed weld). Adjacent cap passes may partially cover, but not completely cover, a cap pass.

***caulking.** Plastic deformation of weld and base metal surfaces by mechanical means to seal or obscure discontinuities.

complete fusion. Fusion over the entire fusion faces and between all adjoining weld beads.

CJP (complete joint penetration). A joint root condition in a groove weld in which weld metal extends through the joint thickness.

***CJP groove weld (statically and cyclically loaded structures).** A groove weld which has been made from both sides or from one side on a backing having CJP and fusion of weld and base metal throughout the depth of the joint.

***CJP groove weld (tubular structures).** A groove weld having CJP and fusion of weld and base metal throughout the depth of the joint or as detailed in Figures 2.4, 4.26, 3.6 through 3.10. A CJP tubular groove weld made from one side only, without backing, is allowed where the size or configuration, or both, prevent access to the root side of the weld.

complete penetration. A nonstandard term for **CJP**.

consumable guide ESW. See **ESW**.

continuous weld. A weld that extends continuously from one end of a joint to the other. Where the joint is essentially circular, it extends completely around the joint.

***contract documents.** Any codes, specifications, drawings, or additional requirements that are contractually specified by the Owner.

***Contractor.** Any company, or that individual representing a company, responsible for the fabrication, erection manufacturing or welding, in conformance with the provisions of this code.

***Contractor's Inspector.** The duly designated person who acts for, and in behalf of, the Contractor on all inspection and quality matters within the scope of the code and of the contract documents.

corner joint. A joint between two members located approximately at right angles to each other in the form of an L.

***cover pass.** See **cap pass**.

CO_2 welding. A nonstandard term for **GMAW** with carbon dioxide shielding gas.

crater. A depression in the weld face at the termination of a weld bead.

***CVN.** Charpy V-notch.

D

***decibel (dB) (UT).** The logarithmic expression of a ratio of two amplitudes or intensities of acoustic energy.

***decibel rating (UT).** See preferred term **indication rating**.

defect. A discontinuity or discontinuities that by nature or accumulated effect (for example total crack length) render a part or product unable to meet minimum applicable acceptance standards or specifications. This term designates rejectability.

defective weld. A weld containing one or more defects.

***defect level (UT).** See **indication level**.

***defect rating (UT).** See **indication rating**.

depth of fusion. The distance that fusion extends into the base metal or previous bead from the surface melted during welding.

***dihedral angle.** See **local dihedral angle**.

discontinuity. An interruption of the typical structure of a material, such as a lack of homogeneity in its mechanical or metallurgical, or physical characteristics. A discontinuity is not necessarily a defect.

downhand. A nonstandard term for **flat welding position**.

***drawings.** Refers to plans design and detail drawings, and erection plans.

E

***edge angle (tubular structures).** The acute angle between a bevel edge made in preparation for welding and a tangent to the member surface, measured locally in a plane perpendicular to the intersection line. All bevels open to outside of brace.

***effective length of weld.** The length throughout which the correctly proportioned cross section of the weld exists. In a curved weld, it shall be measured along the weld axis.

EGW (electrogas welding). An arc welding process that uses an arc between a continuous filler metal electrode and the weld pool, employing approximately vertical welding progression with backing to confine the molten weld metal. The process is used with or without an externally supplied shielding gas and without the application of pressure.

ESW (electroslag welding). A welding process that produces coalescence of metals with molten slag that melts the filler metal and the surfaces of the workpieces. The weld pool is shielded by this slag, which moves along the full cross section of the joint as welding progresses. The process is initiated by an arc that heats the slag. The arc is then extinguished by the conductive slag, which is kept molten by its resistance to electric current passing between the electrode and the workpieces.

consumable guide ESW. An electroslag welding process variation in which filler metal is supplied by an electrode and its guiding member.

***end return.** The continuation of a fillet weld around a corner of a member as an extension of the principal weld.

***Engineer.** A duly designated individual who acts for and in behalf of the Owner on all matters within the scope of the code.

F

***fatigue.** Fatigue, as used herein, is defined as the damage that may result in fracture after a sufficient number of stress fluctuations. Stress range is defined as the peak-to-trough magnitude of these fluctuations. In the case of stress reversal, stress range shall be computed as the numerical sum (algebraic difference) of maximum repeated tensile and compressive stresses, or the sum of shearing stresses of opposite direction at a given point, resulting from changing conditions of load.

faying surface. The mating surface of a member that is in contact with or in close proximity to another member to which it is to be joined.

FCAW (flux cored arc welding). An arc welding process that uses an arc between a continuous filler metal electrode and the weld pool. The process is used with shielding gas from a flux contained within the tubular electrode, with or without additional shielding from an externally supplied gas, and without the application of pressure.

***FCAW-G (flux cored are welding—gas shielded).** A flux cored arc welding process variation in which additional shielding is obtained from an externally supplied gas or gas mixture.

***FCAW-S (flux cored arc welding—self shielded).** A flux cored arc welding process where shielding is exclusively provided by a flux contained within the tubular electrode.

filler metal. The metal or alloy to be added in making a welded, brazed, or soldered joint.

fillet weld leg. The distance from the joint root to the toe of the fillet weld.

flare-bevel-groove weld. A weld in the groove formed between a joint member with a curved surface and another with a planar surface.

***flash.** The material which is expelled or squeezed out of a weld joint and which forms around the weld.

flat welding position. The welding position used to weld from the upper side of the joint at a point where the weld axis is approximately horizontal, and the weld face lies in an approximately horizontal plane.

flux cored arc welding. See **FCAW**.

fusion. The melting together of filler metal and base metal (substrate), or of base metal only, to produce a weld.

***fusion-type discontinuity.** Signifies slag inclusion, incomplete fusion, incomplete joint penetration, and similar discontinuities associated with fusion.

fusion zone. The area of base metal melted as determined on the cross section of a weld.

G

gas metal arc welding. See **GMAW**.

***gas pocket.** A nonstandard term for **porosity**.

***Geometric unsharpness.** The fuzziness or lack of definition in a radiographic image resulting from the source size, object-to-film distance, and source-to-object distance. Geometric unsharpness may be expressed mathematically as:

$$U_g = F (L_i - L_o)L_o$$

Where U_g is the geometric unsharpness, F is the size of the focal spot or gamma radiation, L_i is the source-to-film distance, and L_o is the source-to-object distance.

GMAW (gas metal arc welding). An arc welding process that uses an arc between a continuous filler metal electrode and the weld pool. The process is used with shielding from an externally supplied gas and without the application of pressure.

GMAW-S (gas metal arc welding-short circuit arc). A gas metal arc welding process variation in which the consumable electrode is deposited during repeated short circuits.

gouging. See **thermal gouging**.

groove angle. The total included angle of the groove between workpieces.

***groove angle, ϕ (tubular structures).** The angle between opposing faces of the groove to be filled with weld metals, determined after the joint is fitted up.

groove face. The surface of a joint member included in the groove.

groove weld. A weld made in the groove between the workpieces.

GTAW. Gas tungsten arc welding.

H

HAZ (heat-affected zone). The portion of the base metal whose mechanical properties or microstructure have been altered by the heat of welding, brazing, soldering, or thermal cutting.

heat-affected zone. See **HAZ**.

horizontal fixed position (pipe welding). The position of a pipe joint in which the axis of the pipe is approximately horizontal, and the pipe is not rotated during welding (see Figures 4.1, 4.2, and 4.4).

horizontal welding position, *fillet weld*. The welding position in which the weld is on the upper side of an approximately horizontal surface and against an approximately vertical surface (see Figures 4.1, 4.2, 4.3, and 4.5).

***horizontal reference line (UT).** A horizontal line near the center of the UT instrument scope to which all echoes are adjusted for dB reading.

horizontal rotated position (pipe welding). The position of a pipe joint in which the axis of the pipe is approximately horizontal, and welding is performed in the flat position by rotating the pipe (see Figures 4.1, 4.2, and 4.4).

***hot-spot strain (tubular structures).** The cyclic total range of strain which would be measured at the point of highest stress concentration in a welded connection. When measuring hot-spot strain, the strain gage should be sufficiently small to avoid averaging high and low strains in the regions of steep gradients.

I

***IQI (image quality indicator).** A device whose image in a radiograph is used to determine RT quality level. It is not intended for use in judging the size nor for establishing acceptance limits of discontinuities.

image quality indicator. See **IQI**.

***indication (UT).** The signal displayed on the oscilloscope signifying the presence of a sound wave reflector in the part being tested.

***indication level (UT).** The calibrated gain or attenuation control reading obtained for a reference line height indication from a discontinuity.

***indication rating (UT).** The decibel reading in relation to the zero reference level after having been corrected for sound attenuation.

intermittent weld. A weld in which the continuity is broken by recurring unwelded spaces.

interpass temperature. In a multipass weld, the temperature of the weld area between weld passes.

J

joint. The junction of members or the edges of members that are to be joined or have been joined.

joint penetration. The distance the weld metal extends from the weld face into a joint, exclusive of weld reinforcement.

joint root. That portion of a joint to be welded where the members approach closest to each other. In cross section, the joint root may be either a point, a line, or an area.

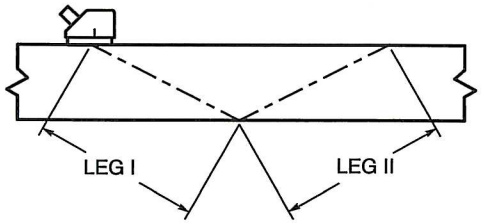
***joint welding procedure.** The materials and detailed methods and practices employed in the welding of a particular joint.

L

lap joint. A joint between two overlapping members in parallel planes.

***layer.** A stratum of weld metal or surfacing material. The layer may consist of one or more weld beads laid side by side.

***leg (UT).** The path the shear wave travels in a straight line before being reflected by the surface of material being tested. See sketch for leg identification. Note: Leg I plus leg II equals one V-path.



leg of a fillet weld. See **fillet weld leg.**

***local dihedral angle, Ψ (tubular structures).** The angle, measured in a plane perpendicular to the line of the weld, between tangents to the outside surfaces of the tubes being joined at the weld. The exterior dihedral angle, where one looks at a localized section of the connection, such that the intersecting surfaces may be treated as planes.

M

***machine welding.** Welding with equipment which performs the welding operation under the constant observation and control of a welding operator. The equipment may or may not load and unload the workpieces. See also **automatic welding.**

manual welding. Welding with the torch, gun or electrode holder held and manipulated by hand. Accessory equipment, such as part motion devices and manually controlled filler material feeders may be used. See **automatic welding, machine welding,** and **semiautomatic welding.**

***MT.** Magnetic particle testing.

N

NDT. Nondestructive testing.

***node (UT).** See **leg.**

***nominal tensile strength of the weld metal.** The tensile strength of the weld metal indicated by the classification number of the filler metal (e.g., nominal tensile strength of E60XX is 60 ksi [420 MPa]).

O

*OEM (Original Equipment Manufacturer). A single Contractor that assumes some or all of the responsibilities assigned by this code to the Engineer.

overhead welding position. The welding position in which welding is performed from the underside of the joint (see Figures 4.1, 4.2, 4.3, and 4.5).

overlap, ***fusion welding.*** The protrusion of weld metal beyond the weld toe or weld root.

*Owner. The individual or company that exercises legal ownership of the product or structural assembly produced to this code.

oxygen cutting (OC). A group of thermal cutting processes that severs or removes metal by means of the chemical reaction between oxygen and the base metal at elevated temperature. The necessary temperature is maintained by the heat from an arc, an oxyfuel gas flame, or other source.

oxygen gouging. Thermal gouging that uses an oxygen cutting process variation to form a bevel or groove.

P

***parallel electrode.** See **SAW.**

partial joint penetration. See **PJP.**

pass. See **weld pass.**

peening. The mechanical working of metals using impact blows.

***pipe.** Tubular-shaped product of circular cross section. See **tubular.**

***piping porosity (ESW and EGW).** Elongated porosity whose major dimension lies in a direction approximately parallel to the weld axis.

***piping porosity (general).** Elongated porosity whose major dimension lies in a direction approximately normal to the weld surface. Frequently referred to as *pin holes* when the porosity extends to the weld surface.

PJP. Joint penetration that is intentionally less than complete.

plug weld. A weld made in a circular hole in one member of a joint fusing that member to another member. A fillet-welded hole shall not be construed as conforming to this definition.

porosity. Cavity-type discontinuities formed by gas entrapment during solidification or in a thermal spray deposit.

positioned weld. A weld made in a joint that has been placed to facilitate making the weld.

***postweld heat treatment.** Any heat treatment after welding.

preheating. The application of heat to the base metal immediately before welding, brazing, soldering, thermal spraying, or cutting.

preheat temperature, *welding*. The temperature of the base metal in the volume surrounding the point of welding immediately before welding is started. In a multiple-pass weld, it is also the temperature immediately before the second and subsequent passes are started.

***PT.** Liquid penetrant testing.

***PWHT.** Post weld heat treatment.

Q

qualification. See **welder performance qualification** and **WPS qualification**.

R

random sequence. A longitudinal sequence in which the weld bead increments are made at random.

***reference level (UT).** The decibel reading obtained for a horizontal reference-line height indication from a reference reflector.

***reference reflector (UT).** The reflector of known geometry contained in the IIW reference block or other approved blocks.

reinforcement of weld. See **weld reinforcement**.

***rejectable discontinuity.** See **defect**.

***resolution (UT).** The ability of UT equipment to give separate indications from closely spaced reflectors.

root face. That portion of the groove face within the joint root.

root gap. A nonstandard term for **root opening**.

root of joint. See **joint root**.

root of weld. See **weld root**.

root opening. A separation at the joint root between the workpieces.

***RT.** Radiographic testing.

S

SAW (submerged arc welding). An arc welding process that uses an arc or arcs between a bare metal electrode or electrodes and the weld pool. The arc and molten metal are shielded by a blanket of granular flux on the workpieces. The process is used without pressure and with filler metal from the electrode and sometimes from a supplemental source (welding rod, flux, or metal granules).

***single electrode.** One electrode connected exclusively to one power source which may consist of one or more power units.

***parallel electrode.** Two electrodes connected electrically in parallel and exclusively to the same power source. Both electrodes are usually fed by means of a single electrode feeder. Welding current, when specified, is the total for the two.

***multiple electrodes.** The combination of two or more single or parallel electrode systems. Each of the component systems has its own independent power source and its own electrode feeder.

***scanning level (UT).** The dB setting used during scanning, as described in Tables 6.2 and 6.3.

semiautomatic welding. Manual welding with equipment that automatically controls one or more of the welding conditions.

shielded metal arc welding. See **SMAW**.

shielding gas. Protective gas used to prevent or reduce atmospheric contamination.

single-welded joint. A joint that is welded from one side only.

size of weld. See **weld size**.

slot weld. A weld made in an elongated hole in one member of a joint fusing that member to another

member. The hole may be open at one end. A fillet welded slot shall not be construed as conforming to this definition.

SMAW (shielded metal arc welding). An arc welding process with an arc between a covered electrode and the weld pool. The process is used with shielding from the decomposition of the electrode covering, without the application of pressure, and with filler metal from the electrode.

***sound beam distance (UT).** See **sound path distance**.

***sound path distance (UT).** The distance between the search unit test material interface and the reflector as measured along the centerline of the sound beam.

spatter. The metal particles expelled during fusion welding that do not form a part of the weld.

stringer bead. A type of weld bead made without appreciable weaving motion.

***stud base.** The stud tip at the welding end, including flux and container, and 1/8 in. [3 mm] of the body of the stud adjacent to the tip.

***stud arc welding (SW).** An arc welding process that produces coalescence of metals by heating them with an arc between a metal stud, or similar part, and the other workpiece. When the surfaces to be joined are properly heated, they are brought together under pressure. Partial shielding may be obtained by the use of a ceramic ferrule surrounding the stud. Shielding gas or flux may or may not be used.

submerged arc welding. See **SAW**.

T

tack weld. A weld made to hold parts of a weldment in proper alignment until the final welds are made.

***tack welder.** A fitter, or someone under the direction of a fitter, who tack welds parts of a weldment to hold them in proper alignment until the final welds are made.

***tandem.** Refers to a geometrical arrangement of electrodes in which a line through the arcs is parallel to the direction of welding.

temporary weld. A weld made to attach a piece or pieces to a weldment for temporary use in handling, shipping, or working on the weldment.

thermal gouging. A thermal cutting process variation that removes metal by melting or burning the entire removed portion, to form a bevel or groove.

throat of a fillet weld.

actual throat. The shortest distance between the weld root and the face of a fillet weld.

theoretical throat. The distance from the beginning of the joint root perpendicular to the hypotenuse of the largest right triangle that can be inscribed within the cross section of a fillet weld. This dimension is based on the assumption that the root opening is equal to zero.

throat of a groove weld. A nonstandard term for **groove weld size**.

T-joint. A joint between two members located approximately at right angles to each other in the form of a T.

toe of weld. See **weld toe**.

***transverse discontinuity.** A weld discontinuity whose major dimension is in a direction perpendicular to the weld axis "X," see Annex D, Form D-11.

tubular.** Tubular products is a generic term for a family of hollow section products of various cross-sectional configuration. The term ***pipe denotes cylindrical products to differentiate from square and rectangular hollow section products. However, a tube or tubing can also be cylindrical. User should note the AISC designation of tubular sections:

TSD × t	for circular tubes (pipe)
TSa × b × t	for square and rectangular tubes (referred to collectively as box sections in this code)

where:

TS = the group symbol
t = nominal wall thickness
D = nominal outside diameter
a = nominal major width
b = nominal minor width

***tubular connection.** A connection in the portion of a structure that contains two or more intersecting members, at least one of which is a tubular member.

***tubular joint.** A joint in the interface created by a tubular member intersecting another member (which may or may not be tubular).

U

undercut. A groove melted into the base metal adjacent to the weld toe or weld root and left unfilled by weld metal.

***UT.** Ultrasonic testing.

V

*Verification Inspector. The duly designated person who acts for, and in behalf of, the Owner on all inspection and quality matters designated by the Engineer.

vertical welding position. The welding position in which the weld axis, at the point of welding, is approximately vertical, and the weld face lies in an approximately vertical plane (see Figures 4.1, 4.2, 4.3, and 4.5).

***vertical position (pipe welding).** The position of a pipe joint in which welding is performed in the horizontal position and the pipe is not rotated during welding (see Figures 4.1, 4.2, and 4.4).

***V-path (UT).** The distance a shear wave sound beam travels from the search unit test material interface to the other face of the test material and back to the original surface.

W

weave bead. A type of weld bead made with transverse oscillation.

weld. A localized coalescence of metals or nonmetals produced by heating the materials to the welding temperature, with or without the application of pressure or by the applications of pressure alone and with or without the use of filler material.

weldability. The capacity of a material to be welded under the imposed fabrication conditions into a specific, suitably designed structure and to perform satisfactorily in the intended service.

weld axis. A line through the length of a weld, perpendicular to and at the geometric center of its cross section.

weld bead. A weld resulting from a pass. See **stringer bead** and **weave bead**.

welder. One who performs a manual or semiautomatic welding operation.

welder certification. Written certification that a welder has produced welds meeting a prescribed standard of welder performance.

welder performance qualification. The demonstration of a welder's ability to produce welds meeting prescribed standards.

weld face. The exposed surface of a weld on the side from which welding was done.

welding. A joining process that produces coalescence of materials by heating them to the welding temperature, with or without the application of pressure or by the application of pressure alone, and with or without the use of filler metal. See also the Master Chart of Welding and Allied Processes in the latest edition of AWS A3.0.

welding machine. Equipment used to perform the welding operation. For example, spot welding machine, arc welding machine, and seam welding machine.

welding operator. One who operates adaptive control, automatic, mechanized, or robotic welding equipment.

welding sequence. The order of making the welds in a weldment.

weld pass. A single progression of welding along a joint. The result of a pass is a weld bead or layer.

weld reinforcement. Weld metal in excess of the quantity required to fill a joint.

weld root. The points, as shown in cross section, at which the root surface intersects the base metal surfaces.

weld size.

fillet weld size. For equal leg fillet welds, the leg lengths of the largest isosceles right triangle that can be inscribed within the fillet weld cross section. For unequal leg fillet welds, the leg lengths of the largest right triangle that can be inscribed within the fillet weld cross section.

Note: When one member makes an angle with the other member greater than 105°, the leg length (size) is of less significance than the effective throat, which is the controlling factor for the strength of the weld.

groove weld size. The joint penetration of a groove weld.

weld tab. Additional material that extends beyond either end of the joint, on which the weld is started or terminated.

weld toe. The junction of the weld face and the base metal.

weldment. An assembly whose component parts are joined by welding.

WPS qualification. The demonstration that welds made by a specific procedure can meet prescribed standards.

***WPS (welding procedure specification).** The detailed methods and practices including all joint welding procedures involved in the production of a weldment. See **joint welding procedure**.